

TECHNOLOGY UTILIZATION

WELDING AND JOINING

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A COMPILATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

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When the subject matter of a particular Compilation is more narrowly defined, its title describes the subject matter more specifically. Successive Compilations in each broad category above are identified by an issue number in parentheses: e.g., the (03) in SP-5972(03).

Divided into three sections, this Compilation presents NASA-developed technology in welding and joining. Section One contains articles on welding equipment and techniques, and Section Two describes general bonding and joining techniques. The third section contains several articles on clamps and other holding fixtures.

Additional technical information on items in this Compilation can be requested by circling the appropriate number on the Reader Service Card included in this Compilation.

The latest patent information available at the final preparation of this Compilation is presented on the page following the last article in the text. For those innovations on which NASA has decided not to apply for a patent, a Patent Statement is not included. Potential users of items described herein should consult the cognizant organization for updated patent information at that time.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this Compilation.

Jeffrey T. Hamilton, *Director*  
*Technology Utilization Office*  
*National Aeronautics and Space Administration*

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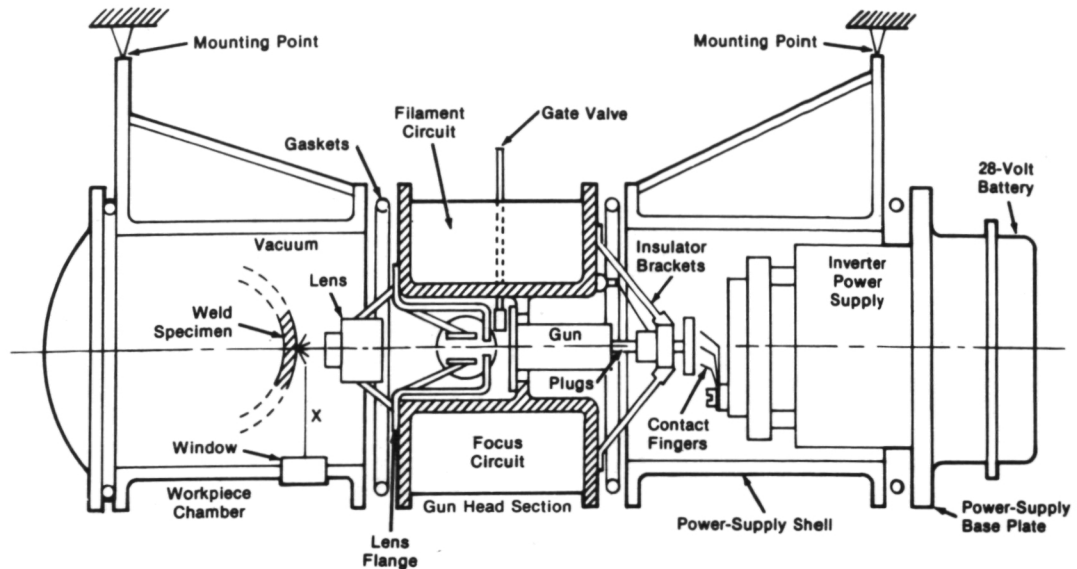
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# Contents

	Page
<b>SECTION 1. WELDING</b>	
Self-Contained Electron Beam Welding Gun . . . . .	1
Finger-Operated Controller on Tungsten Inert Gas (TIG) Weld Torch . . . . .	2
Compound-Curvature Surface-Tracking Provided by New Skate-Weld Carriage . . . . .	3
Portable Electron Beam Weld Chamber . . . . .	4
Weld Peaking and Offset Pocket Gauge . . . . .	5
Semicircular Electrode for Spot-Welding Thermocouples to a Round Specimen . . . . .	6
Small-Aperture Adapter for Oxygen Torches . . . . .	7
2319-T6 Alloy Improves Stud Welding to 2219-T87 Aluminum Alloy Structure . . . . .	7
Strain Gauge Attachment by Spot Welding Reduces the Fatigue Strength of Ti-6Al-4V, Rene 41, and Inconel X . . . . .	8
Joining Precipitation-Hardened Nickel-Base Alloys by Friction Welding . . .	9
Transition Weld Joint for Aluminum/Stainless Steel . . . . .	10
Hole-Drilling Technique for Weld Repair . . . . .	11
Analysis Of Thermal Stress and Metal Movement During Welding . . . . .	11
<b>SECTION 2. BONDING AND JOINING</b>	
Machining and Debrazing Technique for Fluid-Line Joint Removal . . . . .	12
Bonded Joint With Tapered Insert . . . . .	13
Titanium Interleaves Reinforce Boron-Aluminum Joints . . . . .	14
Adhesive for Aluminum Withstands Cryogenic Temperatures . . . . .	15
Laminated Aluminum Plate . . . . .	16
Heat Pipes Solve Brazing and Casting Temperature Problems . . . . .	16
Methods of Splicing and Terminating Aluminum-Shielded Wire and Cable . . . . .	17
<b>SECTION 3. CLAMPS AND HOLDING FIXTURES</b>	
Latch Mechanism . . . . .	18
Adjustable Locking Device . . . . .	19
Flexural Clamp Fitting: A Concept . . . . .	20
Band-Clamp Release Mechanism With Full-Shoe Contact and Positive-Release Kickoff: A Concept . . . . .	21
Pintle-Attaching System . . . . .	22
Ball-and-Socket Quick-Release Mechanism . . . . .	23
Improved High-Temperature Gimbal Joint . . . . .	24
Temporary Holddown Post: A Concept . . . . .	26
<b>PATENT INFORMATION . . . . .</b>	<b>27</b>

# Section 1. Welding

## SELF-CONTAINED ELECTRON BEAM WELDING GUN



X = 15.2-cm (6-in.) is the distance from X-ray source to observer

Electron-Beam Welding Gun

A special electron beam welding gun has been designed for experiments to develop a process to join metals under zero gravity. However, the welder may have commercial uses in the automotive industry, in research institutions, and in the aerospace industry. The electron gun consists of a filament, a focusing electrode, and an anode; it operates at a voltage and current around 20 kV and 100 mA.

The power supply for the filament consists of a control regulator circuit, at or near ground potential, that drives an isolation transformer whose secondary is at -20 kV. A small potentiometer controls the current in a series transistor, feeding the inverter that adjusts the filament current and the beam current. Power (from a battery at a nominal 28 Vdc) is supplied to the filament, focus coils, and the main power supply by the use of individual solid state circuits.

A magnetic lens is used to focus the electron beam, as it comes from the gun, into a fine spot to obtain the necessary power density for welding. The lens is designed so that overheating will not occur.

To prevent a line-of-sight trajectory for molten metal between the workpiece and the electron gun

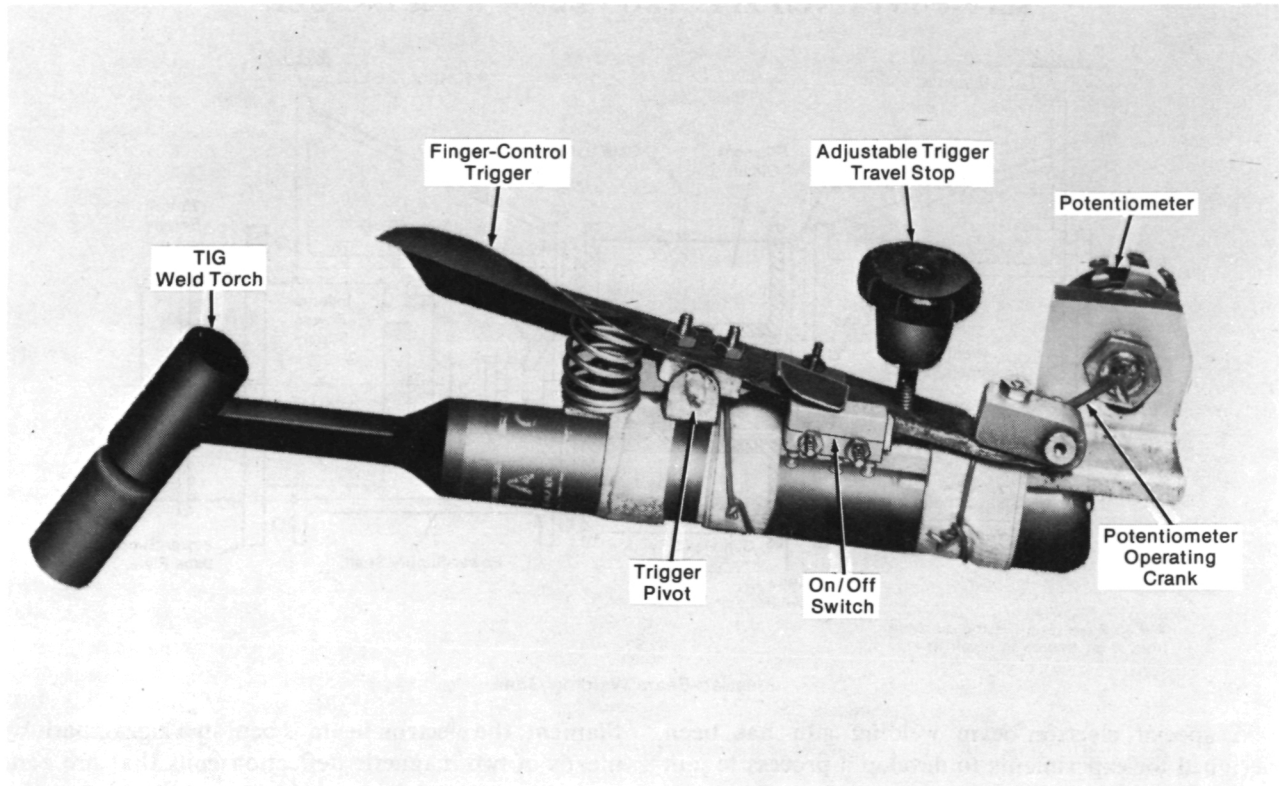
filament, the electron beam is bent in a zigzag path by means of two magnetic deflection coils that are connected in series and powered by a coil current regulator circuit. The magnets are interposed between the gun and the lens and together form one structural unit.

The electron gun, its filament power supply, the deflection coils with their power supply, and the lens with its power supply are all housed in one structural unit called the gun head. The gun head forms the main structural unit of the welder device. The welder operates for periods of up to three minutes. Over-current operating conditions have been encountered, and the over-current protection circuits effectively shut off the inverter before the supply is damaged.

Source: F. A. Elder, J. F. Lowry, and  
R. A. Miller of  
Westinghouse Electric Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-22108)

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# **FINGER-OPERATED CONTROLLER ON TUNGSTEN INERT GAS [TIG] WELD TORCH**



Finger-Operated Controller on Tungsten Inert Gas Weld Torch

A trigger mechanism, mounted directly on the torch handle, controls the welding current in a tungsten inert gas (TIG) weld torch (see figure). The current is controlled by a microswitch and potentiometer. A trigger stop allows fully adjustable constant-current settings. Though similar foot controllers have been used for many years, this new device allows more responsive control during difficult welding operations.

A previous experimental controller required that the operator maintain a constant pressure with his finger to keep current constant. This difficulty is overcome by the adjustable trigger stop shown. As various current settings are used, a maximum value can be set by using the other hand to turn the adjustable stop, to limit trigger travel. In this way the stop can also be released to allow a reduction of the

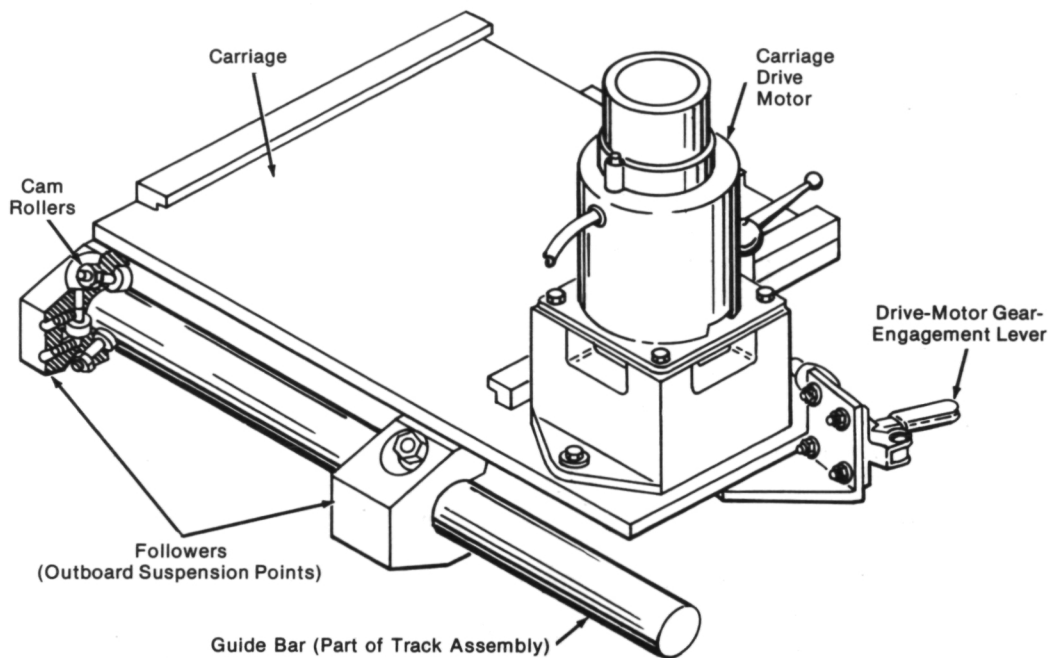
current, or it can be adjusted to a fixed setting to reduce operator fatigue on a long weld.

The device is designed for small torches and may be useful in many industrial welding operations. Various trigger patterns and spring pressures may be provided for different operators or operations. A simplified and more compact design, with an enclosed plastic housing, could be developed for a production model.

Source: G. S. Wasden, E. C. Briggs,  
and J. A. Stein of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17988)

*No further documentation is available.*

# COMPOUND-CURVATURE SURFACE-TRACKING PROVIDED BY NEW SKATE-WELD CARRIAGE



Skate-Weld Carriage

A new carriage-and-track assembly guides fusion-welding units over compound surfaces, as well as simple horizontal, vertical, and circumferential surfaces. It is especially useful where compound-surface skate welding is more economical than manual welding.

This skate-welder carriage, shown in the figure, incorporates a three-point suspension system that permits angular positioning of the weld head. Two followers on the carriage engage a guide bar on the outboard side of the track. The guide bar is positioned by adjustable supports and is formed to the contours of the surface to be welded. The conventional rack-and-pinion drive is replaced with a contoured drive track, incorporating special teeth that mate with a compatible drive gear on the carriage. This driving

mechanism provides positive tracking over the various contours.

Rack-and-pinion drive mechanisms in existing skate welders cannot perform these functions. Flexible tracks are available, but they do not guarantee the positive tracking critical in the fusion-weld process.

Source: J. R. Lewis, K. A. Saenger,  
J. K. Skelly, A. U. Millett, and  
R. Ginez of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-19351)

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## PORTABLE ELECTRON BEAM WELD CHAMBER

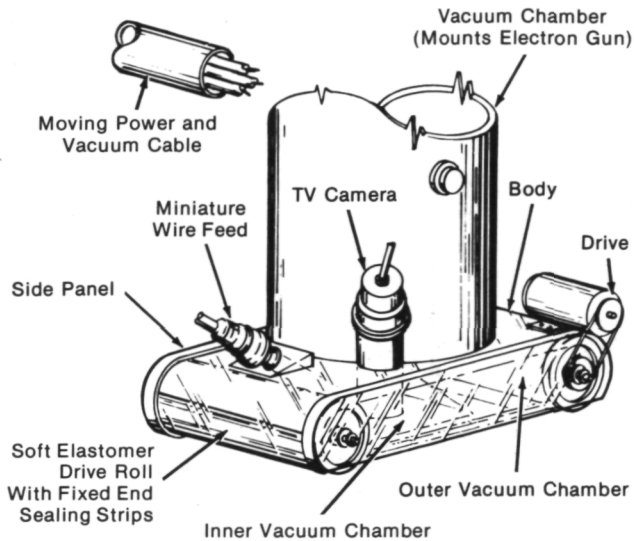


Figure 1. Welding Vacuum Chamber

Conventional electron beam welding requires enclosing the electron beam gun and the object to be welded in a vacuum chamber. This procedure limits the size of the object to be welded.

A small portable vacuum chamber design for skate type electron beam welding has been proposed. It incorporates unique drive tracks and seals to provide adequate vacuum for continuous welding while traveling along the weld path on large parts or structures.

The track driven vacuum chamber and sealing detail as shown in Figures 1 and 2 will mount an electron beam weld head, a television monitor, a miniature wire feed, and a paper tape sealing device. The elastomer tracks, rolls and end seals, along with the hood type inner vacuum chamber, will provide an adequate vacuum in the weld area for present production type electron beam welders. Vacuum connections are provided to both inner and outer chambers.

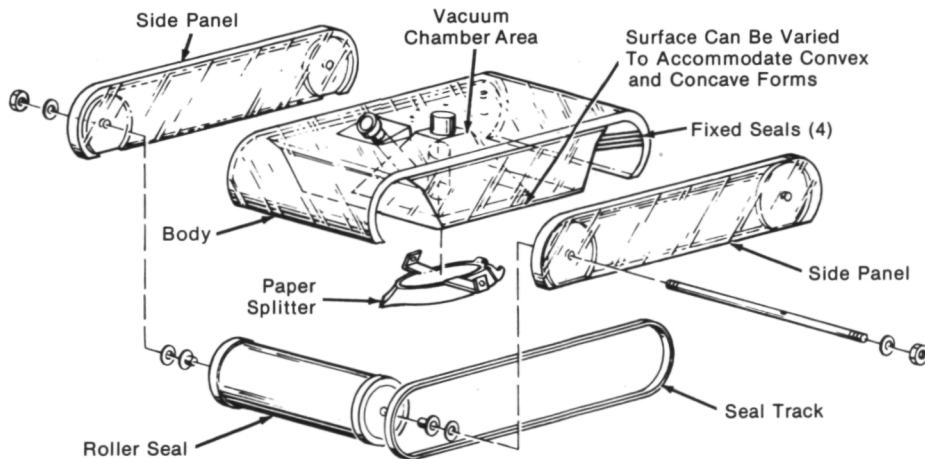
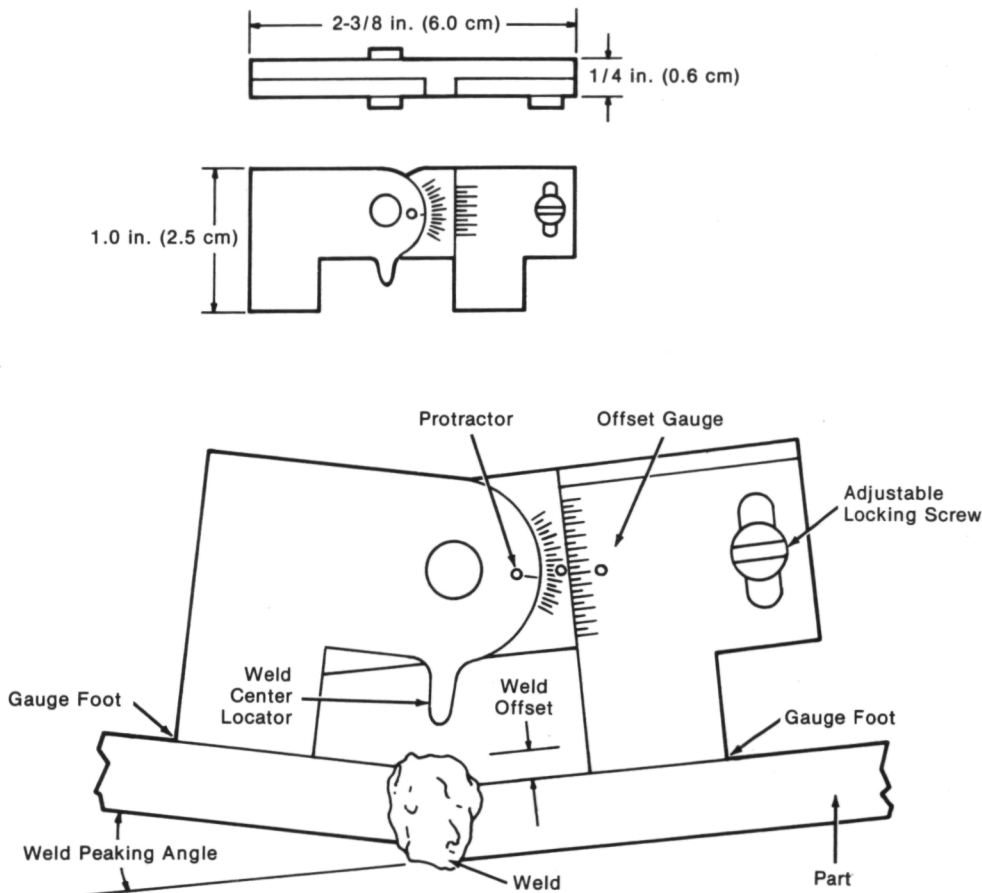


Figure 2. Seal Construction

Source: Jack R. Lewis and James M. Dimino of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17738)

Circle 3 on Reader Service Card.

## WELD PEAKING AND OFFSET POCKET GAUGE



Application of Gauge on a Weld With Peaking and Offset

A gauge for simultaneously measuring offset and peaking angles of a welded assembly is shown in the figure. It consists of an offset indicator coupled to a protractor, and it could prove useful for weldment inspection of butt welds in all fusion-welded structures.

Other types of measuring devices are expensive and usually employ dial micrometers and other cumbersome accessories that are difficult to adjust and apply to localized weld areas. The gauge measures about 6 by 2.5 by 0.6 cm (2-3/8 by 1 by 1/4 in.) and can easily be carried in a pocket.

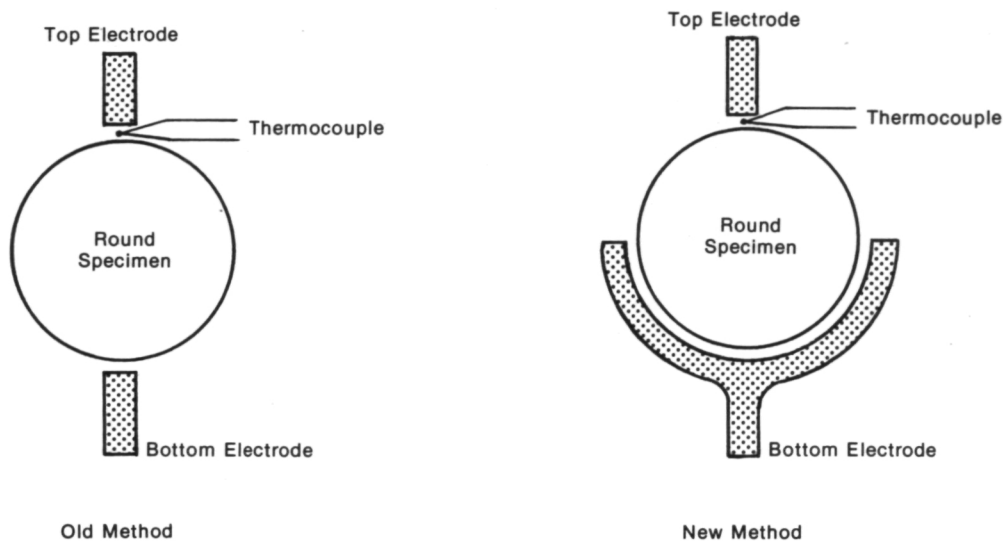
To use, (1) set the protractor at zero degrees, (2) set the offset gauge at zero inches, (3) place the gauge on

the center of the weld, using the weld center locator, (4) adjust the protractor and offset gauge on the part so that each gauge foot contacts the surface of the part over all of each foot-area, and (5) read the weld peaking angle measurement from the protractor and the weld offset measurement from the offset gauge.

Source: K. L. Billington of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-19409)

*No further documentation is available.*

### SEMICIRCULAR ELECTRODE FOR SPOT-WELDING THERMOCOUPLES TO A ROUND SPECIMEN



Semicircular Weld Electrode

A special copper electrode with a U-configuration, used for spot-welding small items to round specimens, is shown in the figure. This specially-shaped electrode holds the bar or tube stock in place and prevents or minimizes slippage of the electrodes. The new electrode permits more accurate thermocouple placement and securely positions the work. This results in decreased spoilage of parts and thermocouples.

Source: J. E. Cobb of  
Rockwell International Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-24427)

*No further documentation is available.*

### SMALL-APERTURE ADAPTER FOR OXYGEN TORCHES

When a very small hot flame is required and standard torch tips are too large, a hypodermic needle may be used instead. The base of the needle has the same tapered inside diameter as the outside diameter of a smaller torch tip. The hypodermic needle is cut to a length of approximately 1.9 cm (3/4 in.) and is fitted over the torch tip. The pressure regulators are adjusted to  $21 \times 10^3 \text{ N/m}^2$  (3 psi) fuel-gas pressure and  $21 \times 10^3 \text{ N/m}^2$  (3 psi) oxygen pressure. The flame at the hypodermic needle tip is adjusted to the job need.

The additional length of the needle makes it easier to work in areas where the standard torch cannot be manipulated. This type of arrangement has been used to weld platinum wires of 0.005 cm (0.002 in.) diameter and to braze electronic components where the heated area must be limited.

The adapter reduces the torch tip aperture by 75 percent. Only expensive special-purpose torches have this feature. The technique could be adapted to torches used in the production and repair of electronic parts, in dental laboratories, in jewelry making and repair, and in miniature machine production.

Source: A. R. Pardoe of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17730)

*No further documentation is available.*

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### 2319-T6 ALLOY IMPROVES STUD WELDING TO 2219-T87 ALUMINUM ALLOY STRUCTURE

Stud welds are widely used by commercial fabricators. A materials-test program for special aluminum stud welds shows that aluminum alloy 2319-T6 has improved stud-weld quality over all others previously used. Tabulated test results may be of design value to those using aluminum stud welds made out of 2319-T6 material.

Standard capacitor-discharge weld-stud design has been used for the study. Weld studs previously used were of 1100, 4043, 5056, 6061, or 6063 aluminum alloys. On initial test specimens the 2319-T3 studs show a large reduction in porosity and cracking as

compared with previously used studs. Further testing is necessary to optimize weld parameters.

Source: E. L. Whiffen of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-19318)

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## STRAIN GAUGE ATTACHMENT BY SPOT WELDING REDUCES THE FATIGUE STRENGTH OF Ti-6Al-4V, RENE 41, AND INCONEL X

Some existing resistance strain gauges and other types under development are attached by spot welding. An experimental investigation was conducted to evaluate the effect of spot welding, as used for instrumentation attachment, on the fatigue behavior of Ti-6Al-4V, Rene 41, and Inconel X.

For the titanium-alloy specimens, a commercially available weldable resistance strain gauge with a metal back was used. The resistance element for the gauge was embedded in compacted magnesium oxide powder and insulated from a small metal tube that was attached to the gauge backing. The metal backs were made from three alloys: a titanium alloy, a gold alloy, and a stainless steel alloy. For the superalloys, weldable strain gauges were simulated by metal foils spot welded to the specimen. The foil alloy was the same as the specimen alloy in both cases.

Fatigue tests were conducted with constant-amplitude axial stresses in the ratio of minimum stress to maximum stress of 0.05 ( $R=0.05$ ). Specimens with and without strain gauges were tested at room temperature  $21^{\circ}\text{C}$  ( $70^{\circ}\text{F}$ ), and superalloy specimens with and without simulated strain gauges were tested at room temperature and at  $815^{\circ}\text{C}$  ( $1500^{\circ}\text{F}$ ).

**Ti-6Al-4V tests:** At  $10^7$  cycles, the fatigue strength of Ti-6Al-4V specimens with weldable gauges was less than one-eighth of that for plain specimens. This effect is much greater than would be expected from stress concentrations resulting from typical structural fabrication. Thus, especially for titanium-alloy structures, the detrimental effect of spot welding should be carefully considered when the use of weldable strain gauges is contemplated.

**Rene 41 tests:** At  $10^7$  cycles, specimens with simulated weldable gauges tested at the two temperatures had the same fatigue strength. For stresses higher than the fatigue strength, the tests at elevated temperature resulted in much shorter fatigue lives than the tests at room temperature. At both temperatures, the

fatigue strengths at  $10^7$  cycles for specimens with simulated weldable gauges were about two-thirds of the value for plain specimens. This result is nearer to that expected from stress concentrations in fabricated structures in contrast to the large difference observed for the titanium alloy.

**Inconel X tests:** The room-temperature fatigue strength, at  $10^7$  cycles, of Inconel X specimens with simulated weldable gauges was about two-thirds that of the plain specimens. However, at  $815^{\circ}\text{C}$  the fatigue strengths of the Inconel X specimens with and without the simulated gauges were the same and somewhat lower than the room-temperature strengths. These effects are of about the same magnitude as usually expected from fabrication effects in structures.

As an aid to understanding the effects of spot welding, a failed specimen of each material was examined metallographically. The examination showed that the effect of spot welding was restricted to very small regions in all three alloys. Spot welding produced nuggets 0.25 mm (0.01 in.) in diameter in the super-alloys. Distinct nuggets were not formed in the titanium-alloy specimens, but spot welding produced microstructural changes within a heat-affected zone about 0.51 mm (0.02 in.) in diameter.

The following documentation may be obtained from:  
National Technical Information Service  
Springfield, Virginia 22151  
Single document price \$3.25  
(or microfiche \$2.25)

Reference: NASA TN D-5973 (N70-41187), Effect of Strain-Gage Attachment by Spot Welding and Bonding on Fatigue Behavior of Ti-6Al-4V, Rene 41, and Inconel X

Source: L. A. Imig  
Langley Research Center  
(LAR-10930)

## JOINING PRECIPITATION-HARDENED NICKEL-BASE ALLOYS BY FRICTION WELDING

The use of precipitation-hardened nickel-base alloys in welded structures has been limited because of cracking that occurs around the welded joints during or after fusion welding. Cracks result from the thermal expansion and contraction that occur during fusion welding, and also from the precipitation of the gamma prime crystalline phase which gives the nickel alloys their precipitation hardening properties. This cracking problem has rendered the higher content, gamma prime-strengthened nickel-base alloys virtually unweldable by even the most advanced fusion welding techniques.

In a recent study, 1.25-cm (1/2-in.) diameter bar stock of a representative precipitation hardening nickel-base alloy (Udimet 700) was successfully butt welded using a stored energy (inertia) friction welding machine. This method of utilizing the discharge of energy from a flywheel to rotate one part to be welded, which is subsequently forced against the other (stationary) part, results in the dissipation of all the energy of the rotating part into the weld interface as the flywheel slows down, thus producing a solid-state weld of excellent quality. The welding process cleans and heats the weld interface and also forces out surface material containing impurities, leaving only fresh, but unmelted, metal to form the solid-state

weld. After post-heating in a furnace, the weld line was not detectable in the recrystallized structure.

A series of such welds was tested and found to be equal in strength to the parent metal in tensile and stress rupture tests at 760° C and 980° C.

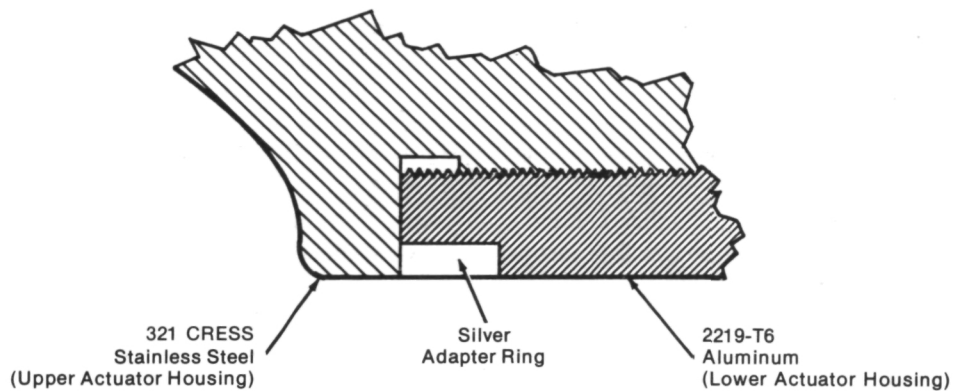
Friction welding requires rotation of one of the parts to be welded, but where applicable, it is an ideal process for high-volume production jobs. The friction welding technology developed in this study is believed to be applicable to other precipitation-hardened nickel-base alloys (such as IN-100 and other gamma prime-strengthened materials) which heretofore have been virtually unweldable.

The following documentation may be obtained from:

National Technical Information Service  
Springfield, Virginia 22151  
Single document price \$3.25  
(or microfiche \$2.25)

Reference: NASA TM-X-2411 (N72-11431/LK),  
An Exploratory Study of Friction Welds in Udimet  
700 and TD-Nickel Bar

Source: T. J. Moore  
Lewis Research Center  
(LEW-11514)

**TRANSITION WELD JOINT FOR ALUMINUM/STAINLESS STEEL**

Transition Weld Joint Used in a Thermal Actuator

The problem of welding a stainless steel valve part to a mating aluminum part has been solved by using an annular silver spacer-ring between the materials. The figure shows a silver spacer inserted between the stainless steel and aluminum alloy parts of a thermal actuator. This spacer permits the parts to be bonded by electron-beam welding. Because of the relative compatibility of silver with both stainless steel and aluminum alloy, the technique produces a weldment of high integrity. Joining stainless steel to aluminum alloy is often necessary in the fabrication of

cryogenic equipment, and this method would be a useful adjunct to other bonding processes such as friction joining.

Source: R. L. Rhoton and D. W. Richman of  
McDonnell Douglas Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-22313)

*Circle 5 on Reader Service Card.*

## HOLE-DRILLING TECHNIQUE FOR WELD REPAIR

An improved technique for the repair of welds in aluminum alloys, utilizing drilled holes rather than machined grooves, has been developed to remove defect areas located by nondestructive testing. The technique minimizes the amount of repair welding required and improves the final mechanical properties of repaired joints. Repair costs are reduced by over 50 percent because the number of weld passes and the degradation of joint mechanical properties are minimized.

Care must be exercised with this technique to ensure that the droptrough is aligned with the drill holes during welding. This is critical when formation of the underbead is being observed. When larger-diameter drill holes are being used, it may be

necessary to run a remelt pass in order to obtain the required penetration and fusion of the drilled-out area.

Detailed welding parameters are available for drill-hole sizes to a maximum of 0.477 cm (3/16 in.). This diameter has been determined to be the maximum for repair-weld reliability using this technique.

Source: C. E. Oleksiak of  
Rockwell International Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-24270)

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## ANALYSIS OF THERMAL STRESS AND METAL MOVEMENT DURING WELDING

An important problem in the fabrication of large aluminum-alloy structures is the control of distortion caused by welding. Frequently, components of such structures must be fabricated to close dimensional tolerances, such as in aerospace applications. Unacceptable distortion that occurs during the welding of joints in these structures often cannot be corrected without removal of the joint. Distortion can also cause mismatching of weld joints which result in the reduction of joint strength.

The present production practices have treated distortion with empirical solutions to individual problems. However, little has been known about the mechanisms causing such distortions. As a result, a study was performed with the following objectives:

1. An investigation of temperature changes caused by the welding arc, which includes an analysis of temperature distribution due to the heat generated by the welding arc;
2. The development of a system of mathematical statements describing the phenomenon of thermal stresses and plastic strains during welding; and

3. The development of a system of mathematical solutions and computer programs for one-dimensional analysis.

Results of this study are published in a report which also includes a brief technical background of the analysis and control of weld distortion. In addition, the report develops a computer program that describes the longitudinal stress obtained after a welding operation.

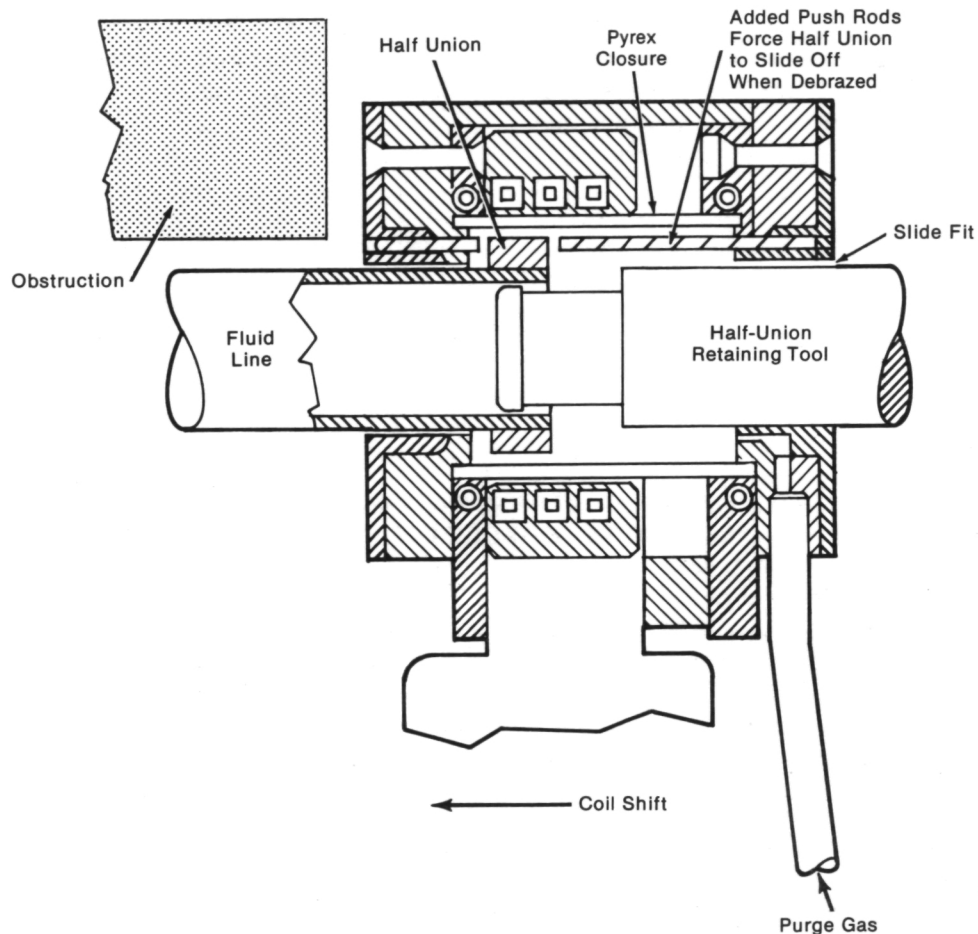
Source: J. B. Andrews and K. Masubuchi of  
Department of Naval Architecture and  
Marine Engineering of  
Massachusetts Institute of Technology  
under contract to  
Marshall Space Flight Center  
(MFS-20984)

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## Section 2. Bonding and Joining

### MACHINING AND DEBRAZING TECHNIQUE FOR FLUID-LINE JOINT REMOVAL



Modified Induction Brazing Tool

A new technique for machining and debrazing unions to remove locked in sections of brazed fluid lines utilizes a special machining tool to cut the line between the tube ends. A modified inert gas induction-brazing tool with a special holder-insert is then used to remove the remaining half-union by debrazing. Since major system disassembly is not required, this technique saves time and costs, compared with the machined removal of couplings.

The use of a special holder-insert (see illustration) to catch and retain the half-coupling as it is debrazed and slid off the fluid line end protects the Pyrex tool liner from possible damage.

For a clean break, a braze filler material that is not reactive with the parent metal should be used. The technique should be useful in high reliability limited-access repair areas.

Source: J. A. Stein of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-19168)

*No further documentation is available.*

### BONDED JOINT WITH TAPERED INSERT

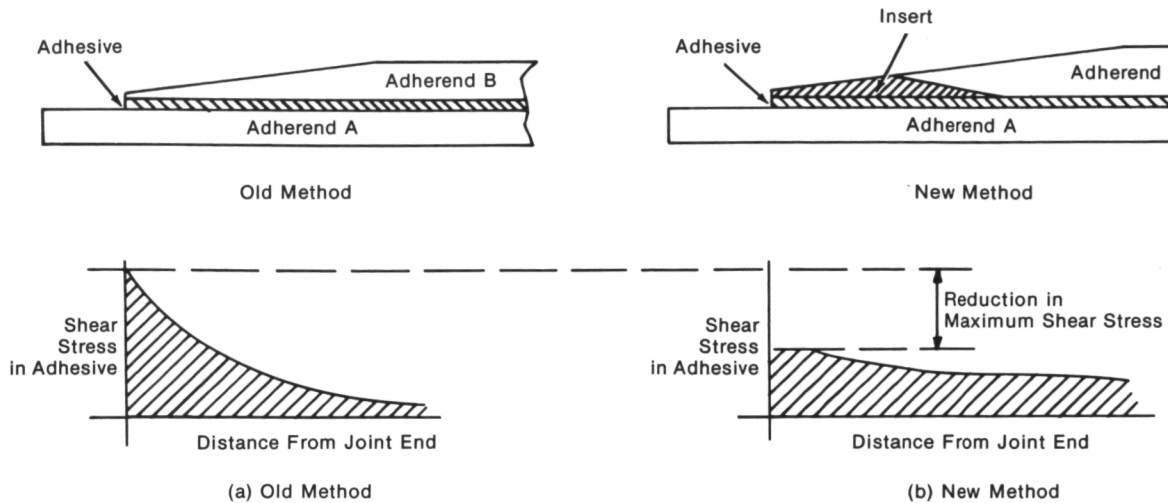


Figure 1. Stress-Distribution In Bonded Joints



Figure 2. Two Methods of Fabrication

A tapered insert reduces the bond (adhesive) shear stress at the ends of bonded joints where load transfer tends to be high. This stress is caused by the relative difference in stiffnesses between pieces being bonded (A and B in Figure 1). The end of piece B is tapered to reduce the discontinuity in stiffness, as shown on the left of the figure. However, when bonding a high-modulus fiber composite (piece B) to a lower modulus material (piece A), the minimum-thickness taper is often inadequate to reduce the shear stresses sufficiently in the adhesive. Thus delamination frequently occurs at the end of the joint, giving rise to a low fatigue life and a weak joint.

The value of the shear stress in the adhesive layer may be reduced to a satisfactory level by inserting a few layers of low-modulus material between A and B (Figure 1). Figure 2 illustrates two methods of fabricating the low-stiffness taper.

A computerized program for the analysis and optimum design of bonded tapered joints has been used to define the joint geometry. The data input includes the design-allowable adhesive shear stress and adherend direct stresses so that the geometry of the taper would result in a satisfactory stress field. This computer analysis showed that a tapered insert could reduce the adhesive peak shear stress by approximately 53 percent.

Source: John B. Sainsbury-Carter of  
United Aircraft Corp.  
under contract to  
Langley Research Center  
(LAR-10900)

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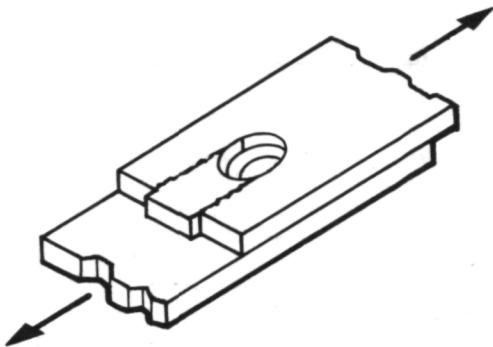
**TITANIUM INTERLEAVES REINFORCE BORON-ALUMINUM JOINTS**

Figure 1. Shear-out Failure on Unidirectional Boron Aluminum

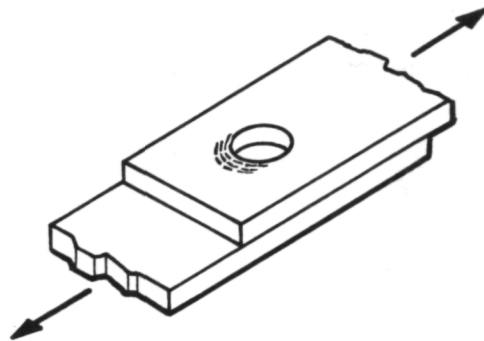


Figure 2. Titanium Reinforced Boron Aluminum After Stress

When mechanical fasteners are used for joining unreinforced, unidirectional, boron-aluminum loaded in the longitudinal direction, joint failure may be caused by shear stresses (see Figure 1). This type of failure generally occurs at stress levels well below the longitudinal compressive or tensile strength of the material and is caused by the relatively low shear strength of the aluminum matrix.

When titanium interleaves are used to reinforce boron-aluminum joints, failure is less likely to occur. Titanium is used to reinforce the joints because it is compatible with the bonding process for joining boron-aluminum monolayer material. Moreover, it possesses a high strength/density ratio at both room and elevated temperatures, and has a coefficient of thermal expansion similar to boron-aluminum. No other readily available, conventional material possesses all these qualifications. However, the use of

titanium in any commercial application must be evaluated in terms of the high cost of titanium.

Predicted fastener design curves have been developed for unidirectional boron-aluminum combined with various numbers of titanium interleaves. Tests show that when the thickness of titanium plies makes up about 30 percent of the total thickness, the allowable fastener load increases to about 2500 kg, compared to about 650 kg when no titanium is used.

Source: O. R. Otto, R. E. Bohlmann,  
and F. J. Vyzral of  
McDonnell Douglas Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-22806)

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### ADHESIVE FOR ALUMINUM WITHSTANDS CRYOGENIC TEMPERATURES

Existing adhesives used for bonding parts to aluminum alloys at room temperatures are prone to failures at cryogenic temperatures. The reason for such failures is the large difference in coefficients of contraction for the metal and the adhesive in cryogenic temperature ranges.

Tests on a polyurethane adhesive which is mixed to various proportions with milled glass fibers have shown that it can match the thermal characteristics of 2014-T6 aluminum at cryogenic temperatures.

Monostrain specimens were fabricated which consisted of a polyurethane adhesive system, 1 percent by weight of silane, and different experimental percentage quantities of milled glass (length 1/32 in. or 0.79 mm) fibers. The quantity of milled fibers was varied from 15 to 65 percent to determine their effect on the physical characteristics of the polyurethane adhesive. Samples were made of the 68.58-cm (27-in.) adhesive composite and were cured at room temperature for at least seven days prior to the tests. The samples were then tested down to 125 K ( $-300^{\circ}$  F) for coefficient of contraction ( $\Delta L/L$ , where  $L$  is the length of the sample), the tensile modulus ( $E$ ), the ultimate tensile strength, and the percentage of elongation at failure.

Results of these tests showed that, with 15-percent glass fibers, the coefficient of contraction from room temperature to 125 K was approximately 0.0072; with 65-percent glass fibers, however, the contraction was

approximately 0.0033. The tensile modulus at 125 K varied from  $7.38 \times 10^9$  to  $11.73 \times 10^9$  N/m<sup>2</sup> ( $1.07 \times 10^6$  to  $1.70 \times 10^6$  psi) for 15- and 65-percent fiber content, respectively. The ultimate tensile stress at 125 K varied from  $75.90 \times 10^6$  to  $10.01 \times 10^7$  N/m<sup>2</sup> (11000 to 14500 psi) and showed a slight increase toward the 65-percent fiber content. Percentage of elongation of the samples before the breakage varied from 1.22 to 0.72 percent with a slight decrease for larger proportions of fiber contents.

Additional tests of the metal-to-metal lap shear strength performed on the polyurethane containing 30, 50, and 65 percent of glass fibers were conducted at room temperature and 125 K. Results revealed that the sample shear strength was  $41.4 \times 10^6$  N/m<sup>2</sup> (6000 psi) throughout at 125 K, which exceeded the  $27.6 \times 10^6$  N/m<sup>2</sup> (4000 psi) requirement.

Shear strengths on all samples at room temperature exceeded the  $6.9 \times 10^6$  N/m<sup>2</sup> (1000 psi) by 12 to 50 percent.

Source: W. L. Hill, T. Matsuoka, and J. C. Helf of  
Rockwell International Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-16848)

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## LAMINATED ALUMINUM PLATE

A composite, diffusion-bonded, aluminum-to-aluminum material has been tested for flaw-growth control and fatigue life. The results are believed to be helpful and new. Cyclic fatigue life of structural materials has been a design problem for some time, and the study yields information which is valuable in preventing fracture in the presence of discontinuities. For instance, laminate thickness is found to have an optimizing effect on fatigue life. At the same gross stress, laminates produced a 65 percent increase in cyclic life over monolithic specimens tested for flaw growth and failure life.

Roll diffusion-bonded material with 2219-T87 aluminum alloy structural layers and soft 1100 aluminum interlayers was tested. Flaw growth testing showed that the laminated material had a cyclic life-to-leakage much greater than monolithic 2219-T87 plate. It was shown that flaw growth is delayed at

a soft interlayer in the laminated material. The delay can be used to give a longer fatigue life or to permit a larger initial flaw. Interlayer thicknesses of 0.010 cm (0.004 in.), 0.020 cm (0.008 in.), and 0.030 cm (0.012 in.) were investigated, and the 0.010-cm interlayer thickness was shown to be the most effective. The relation of flaw depth to cycles could not be determined, and no relation between flaw width and depth could be established.

Source: M. J. Martin and R. G. Micich of  
Grumman Aerospace Corp.  
under contract to  
Johnson Space Center  
(MSC-14442)

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## HEAT PIPES SOLVE BRAZING AND CASTING TEMPERATURE PROBLEMS

Although heat pipes are a relatively recent development they are now commercially available and provide a means for achieving high heat transfer. Heat pipes may be applied during a brazing process to isothermalize the assembly. Parts with large differences in section thicknesses present a control difficulty, since the temperature in thick sections lags behind the temperature in thin sections. In addition, by providing a means of high heat transfer, heat pipes tend to decrease the required brazing-furnace cycle time.

Another possible use would consist of inserting heat pipes in molds to provide directional solidification in casting. A problem with many metal castings is premature freezing in the passages that supply liquid

metal to the castings. This causes voids in the cast parts as they cool and contract. Heat pipes placed in the molds could enable smaller passages to remain open without freezing. Since castings which contain voids are scrap, using heat pipes would permit a higher casting yield and reduce material costs.

Source: G. A. Niblock, R. V. Masek, and  
P. P. King of  
McDonnell Douglas Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-22756)

*Circle 12 on Reader Service Card.*

## METHODS OF SPLICING AND TERMINATING ALUMINUM-SHIELDED WIRE AND CABLE

Methods have been developed for highly reliable solderless splicing of aluminum-shielded wire and cable for seven different types of connections. The techniques may be used for any application that requires aluminum-shielded wire and cable.

The seven types of connections are: (1) deadended (floating) shield, (2) shield pigtails, crimped splice, (3) shield leads, solder-sleeve termination, (4) shield-to-shield contact grounding, shield termination, (5) shield splice, pigtail-spliced cables, (6) shield splice, in-line-spliced cables, and (7) shield splice, individual cable shields to overall shield at connector backshell.

Step-by-step procedures and diagrams for each of the seven types of connections and material, equipment, product-quality verification, and safety requirements are available in detail.

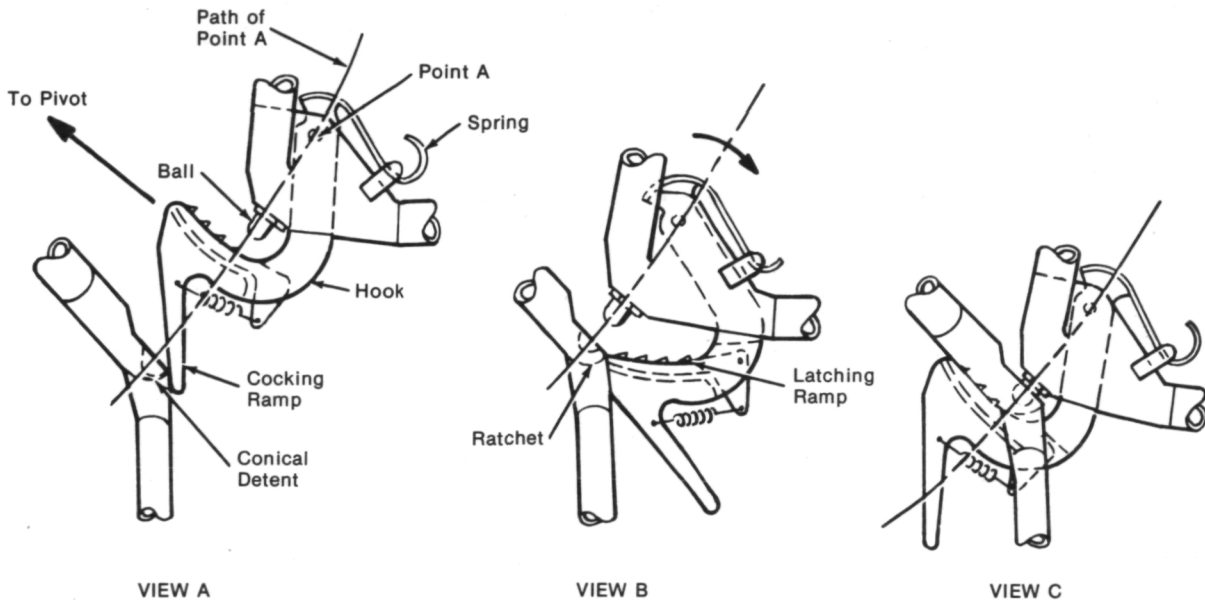
Source: Charles A. Hudak of  
Martin Marietta Corp.  
under contract to  
Langley Research Center  
(LAR-11377)

*Circle 13 on Reader Service Card.*

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## Section 3. Clamps and Holding Fixtures

### LATCH MECHANISM



Latch Locking Sequence

A recently-developed latch mechanism will positively lock two pivoted structures upon contact. It requires no auxiliary power source. The mechanism has a ratchet device that transfers loads imposed on the latch to the support structure before the loads have to be resisted by the latch springs.

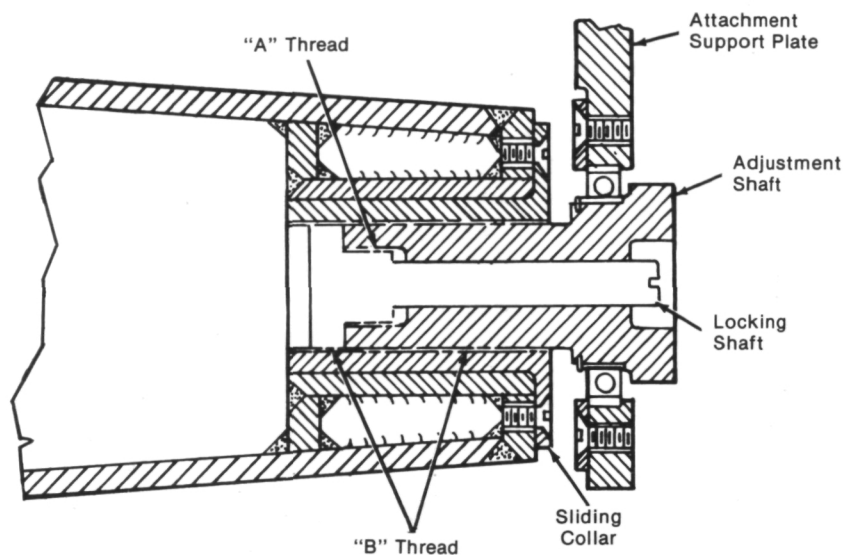
Most latch mechanisms have a small amount of slack, or play, that is usually removed after locking through use of an auxiliary power source, or the latch is precocked to a preloaded position. This particular latch mechanism positively locks the two structures on contact and is irreversible prior to completion of latching. The device is capable of carrying loads in all directions, will latch when misaligned, and has zero slack in low load levels. The latch system is passive in that it uses no external power, and it is not precocked. The loads resisted by the latch are required to go through a rigid structure or through a friction interface before the preloaded spring force resists it.

As the structures approach each other (View A), the cocking ramp pivots the hook about point A, cocking the latch. In this position the hook is cocked and preloaded to force the hook into the latched position. As the two structures close together (View B) contact is made at the ball and conical detent forcing the structures towards an aligned position. As this is taking place, the hook is closed while contacting the latching ramp. During this time the ratchet teeth are engaging to prevent back-up beyond a ratchet tooth. The spring load on the hook, and the latching ramp acts as a wedge forcing the structures together (View C).

Source: G. W. Ulrich of  
McDonnell Douglas Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-21606)

Circle 14 on Reader Service Card.

## ADJUSTABLE LOCKING DEVICE



Conventional methods of taking up end play of a shaft along its longitudinal axis involve the use of a sliding collar with set screws provided for holding the collar in place in some preset position on the shaft. The adjustable locking device is a device for taking up the end play of a shaft without displacing the shaft radially. Coincidentally threaded collars fastened to one or both ends of the shaft are threaded in and out of one another for adjustment of end play.

As shown in the illustration, when the locking shaft is advanced or retracted within the adjustment shaft, a point is reached at which the external threads on the shafts aline and coincide. As long as the coincidental relationship is maintained, the shaft assemblies may be adjusted to any point along the internally threaded collar. However, any differential movement of the locking shaft with respect to the main load carrying adjustment shaft will immediately threadlock the locking shaft at that position within the threaded collar. This locking capability stems from the fact that threads "A" and "B" (see figure) due to differences in size and thread pitch, have different translatory characteristics with respect to each other for the same angular or rotational movement. The differential

threading causes all threads of both shafts to be brought into bearing and enhances the locking capability of the device.

An intrinsic feature of the adjustable-locking device is its ability to be locked in any translatory position without additional axial displacement of the shaft. Some possible uses of this feature would be the removal of end play from large rotating shafts without costly disassembly and shimming operations, provision for quick and accurate alinement for conveyor systems, and provision for adjustment capability for leveling and installing machinery and other equipment. This feature would also permit precise but variable adjustment to tooling fixtures and similar devices for converting them from single purpose to multipurpose tools.

Source: O. J. Fincannon of  
McDonnell Douglas Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-21650)

*Circle 15 on Reader Service Card.*

## FLEXURAL CLAMP FITTING: A CONCEPT

The clamp fitting shown in the figures attaches to the ends of a band clamp. When the clamp is installed, the retaining fastener is allowed to pivot, and the bending moment induced by tightening the retaining fastener is gradually removed by bending of

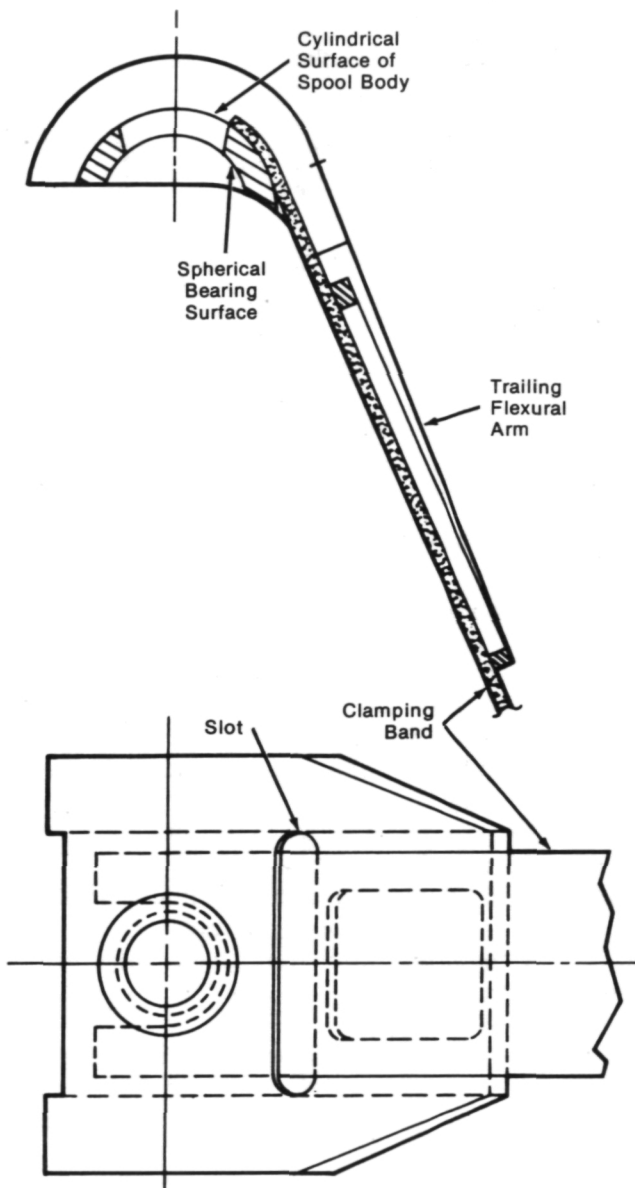


Figure 1. Flexural Clamp Fitting

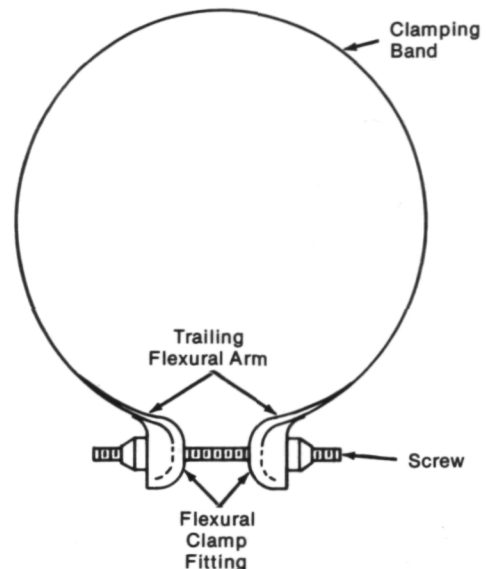


Figure 2. Flexural Clamp Fittings in Use

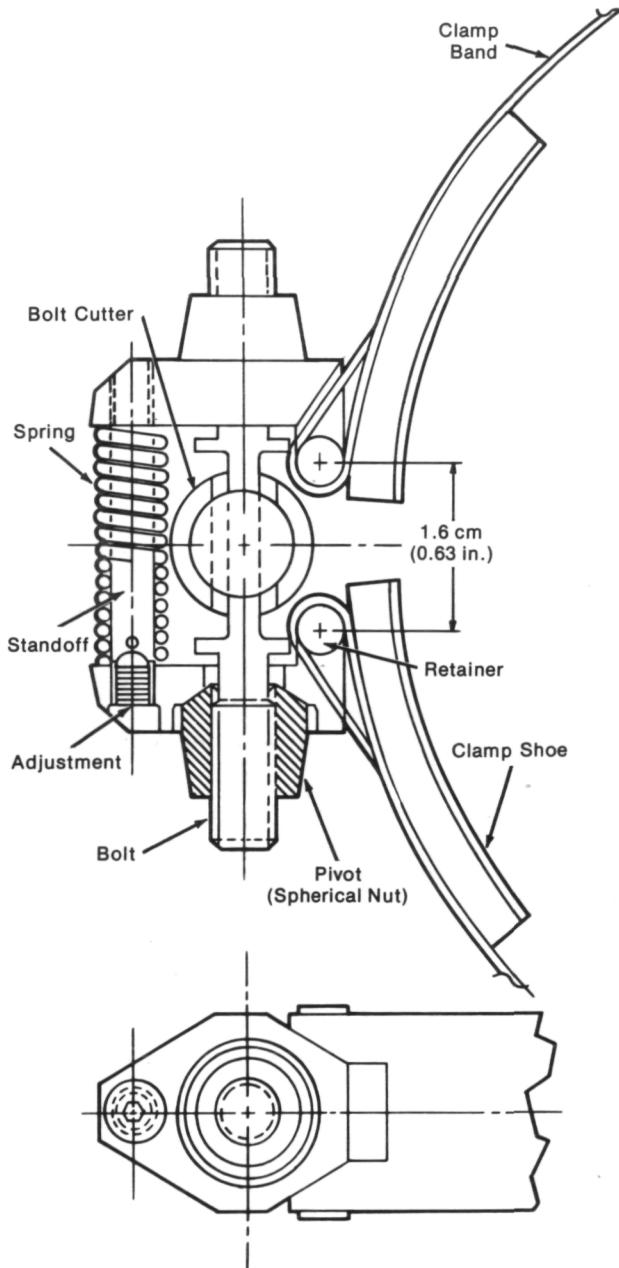
the flexure. The fitting is similar to half of a thread spool with the addition of a trailing flexural arm, a spherical bearing and clearance hole to accommodate the retaining fastener, and a slot through which the clamping band passes to be welded to the cylindrical surface of the spool body (Figure 1).

The advantages of the fitting are the following: (a) The clamping band is fastened to the clamp fitting under pure shear stress instead of the partial peel stress that occurs in conventional slotted-loop ends; (b) no slot is required in the clamping band, since the band is attached directly to the fitting; (c) the moment loading induced by the retaining fastener is distributed to the band by the bending of the flexure; and (d) a high-force long-travel positive-releasing "kick" is obtained after the retaining fastener is sheared remotely. The flexure acts positively to straighten the band and pull the clamp shoes away from the flanges (Figure 2).

Source: Paul A. Dillard of  
Martin Marietta Corp.  
under contract to  
Langley Research Center  
(LAR-11222)

*No further documentation is available.*

### BAND-CLAMP RELEASE MECHANISM WITH FULL-SHOE CONTACT AND POSITIVE-RELEASE KICKOFF: A CONCEPT



Band-Clamp Release Mechanism

The major problems of remote release of clamps that use a tensioned band to press clamp shoes over the flanges of mating parts are solved by a band-clamp release mechanism. The problems are (a) positive clamping pressures are not exerted in the area under the release device, (b) positive expulsion devices that separate the clamp ends and pull them free of the residual fastener parts usually have loose parts after release, and (c) existing mechanisms do not permit band-tension adjustments except through the bolt.

The figure shows a mechanism with the following advantages over existing devices:

- (a) There is a minimum unsupported clamp length of only 1.6 cm (0.63 in.). This length, provided by the mechanism, is necessary to clear the boltcutter during release.
- (b) The mechanism provides direct tangential force to the clamp ends, wedges the clamp shoe, and straightens the band. The rolling action of this force, due to leverage, will overcome any tendency of the clamp to hang up, due to galling or other reasons.
- (c) When parts must be assembled and disassembled, an adjustment resets the clamp to the desired tension after parts wear in.

The clamp may be used with positive-retention and remote-release systems requiring reliability, such as pipe flanges in mining and petroleum production. The device also may be useful in hazardous environments such as nuclear plants.

Source: Paul A. Dillard of  
Martin Marietta Corp.  
under contract to  
Langley Research Center  
(LAR-11223)

*No further documentation is available.*

## PINTLE-ATTACHING SYSTEM

A pintle is an upright pivot pin on which another part may turn. As such, it may be subject to interface bending loads. The pintle-attaching system shown in Figure 1 eliminates interface bending loads when it is used to join two major structural assemblies (Figure 2). The pintle allows one major assembly (structurally supported by four trusses) to be preloaded and connected to four corresponding attach-points on another structural assembly. The basic design consists of a support fitting attached to the load-carrying structure that supports a pintle. The structure being

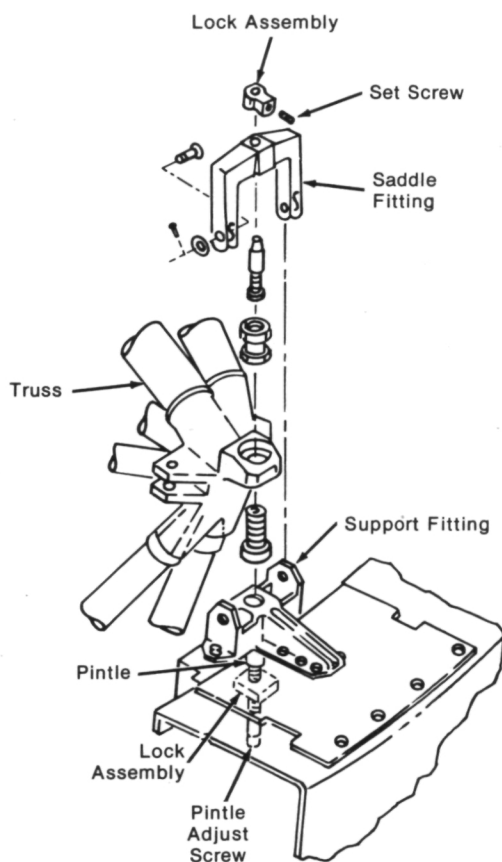


Figure 1. Pintle-Attaching System

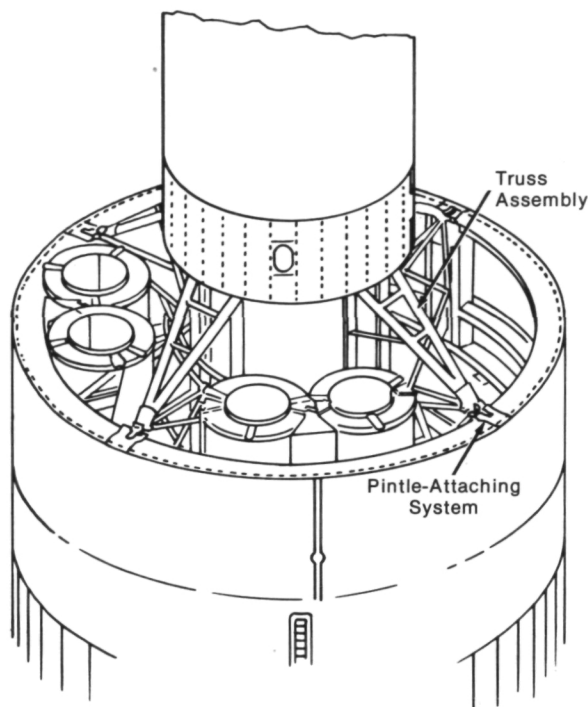
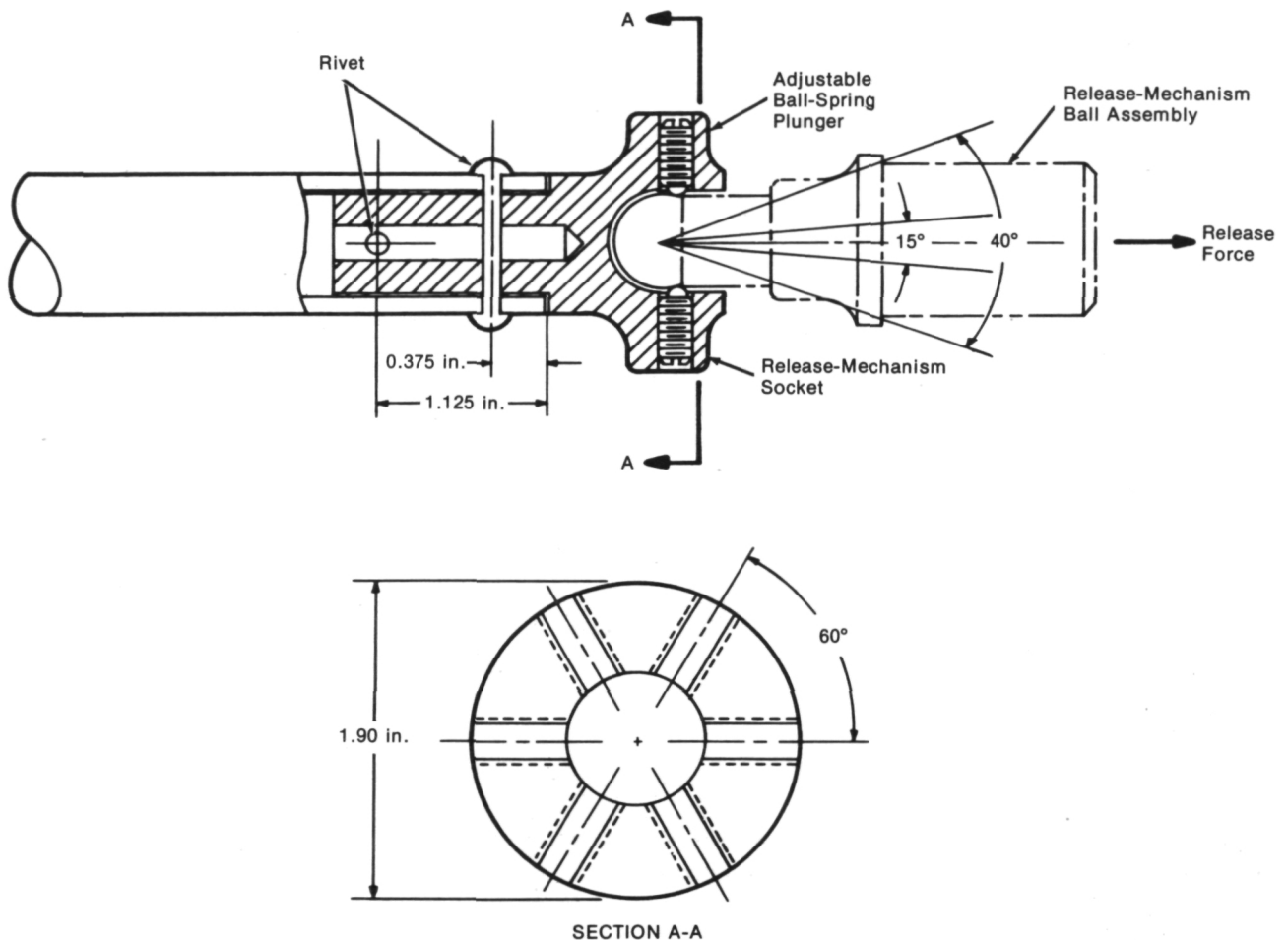


Figure 2. Truss-Joined Structural Assemblies

supported has a pintle-mating fitting attached to a saddle fitting. The saddle fitting also connects to the support fitting and provides the capability of preloading the pintle to react to negative loads.

The advantages of this pintle-attaching system are the following: (a) No in-plane bending loads are carried through the structure being supported, (b) The attach-points carry loads in all directions about the pintle, and (c) The pintle can be adjusted when aligning the two structures for mating. The system might be useful in the attachment of various structural assemblies to industrial machines or cranes.

Source: H. B. Baines of  
McDonnell Douglas Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-21934)

**BALL-AND-SOCKET QUICK-RELEASE MECHANISM**

Ball-and-Socket Quick-Release Mechanism

A recently developed ball-and-socket quick-release mechanism incorporates six threaded adjustable ball plungers that may be set precisely to determine the separation force. The separation force thus may be adjusted to any value between 0 and 178 N (0 and 40 lb). The ball socket is designed to limit the angular motion of the ball insert to a range of 15° to 40°, thus preventing the inadvertent separation of the two (see figure).

Prior techniques involved custom-made devices that were adjusted by forming the socket fingers to provide clamping on the ball insert. These were difficult to adjust for a given separation force, and results were not necessarily repeatable. Also, an excessive lateral force could release the ball socket inadvertently.

With the ball insert fitted to an element that is to be attached to a remote structure and the ball socket attached to the end of a pole, an interface joint is formed which may be separated easily with a specific predetermined pull force. This arrangement may be useful in the service or repair of equipment in otherwise inaccessible areas.

Source: A. J. Lancki  
Johnson Space Center  
(MSC-14572)

Circle 17 on Reader Service Card.

### IMPROVED HIGH-TEMPERATURE GIMBAL JOINT

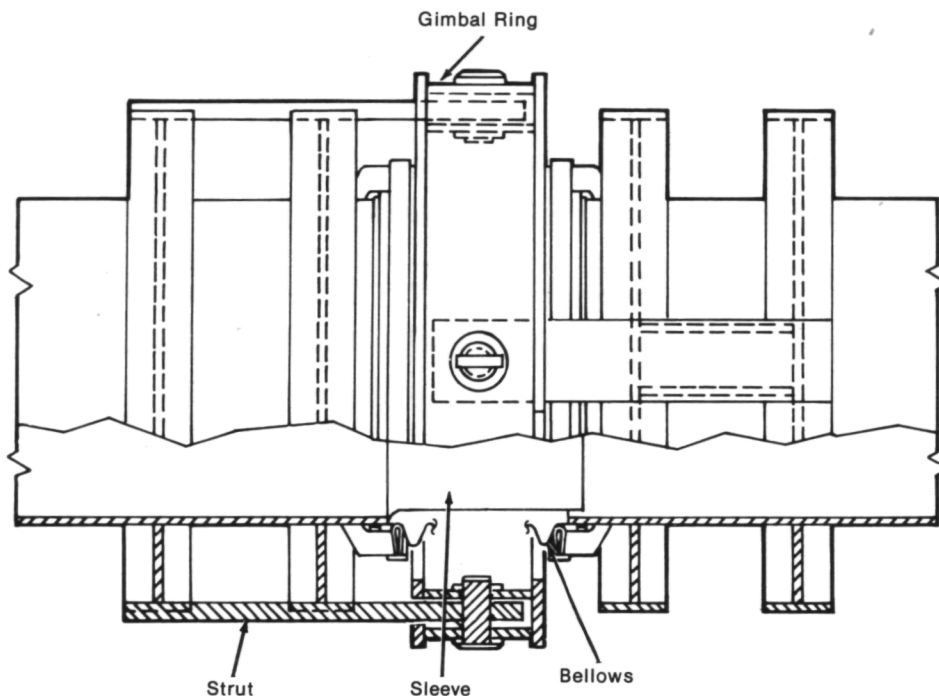


Figure 1. Conventional Design

A bellows gimbal joint for high-temperature use has been designed which reduces thermal stress problems encountered with joints of conventional design.

Conventional joint design is shown in Figure 1. Thrust rings welded to the pipe upstream and downstream of the bellows are connected to a central floating gimbal ring by struts alternately located 90 degrees apart. The upstream and downstream struts are connected to this floating ring with pins to form a double clevis gimbal joint. This arrangement permits thermal expansion of the piping system by angulation. In use, this joint must be brought up to operating temperature slowly and cooled down slowly, with supplemental heating of the thrust rings, to limit thermal stresses and prevent structural failure.

Joints of this type were required for use in large diameter lines conveying gases that undergo rapid and extreme temperature changes. The stress problems inherently caused by such conditions were minimized by an improved joint design.

The improved joint design is shown in Figure 2. The improvement consists essentially of attaching the thrust rings to the pipe with conical sections. This eliminates severe radial thermal gradients and mechanical restraints. The joint assembly is transformed to that of a varying diameter pipe subjected to a nonlinear longitudinal temperature variation. A minor structural discontinuity occurs at the high-temperature, high thermal gradient region where the

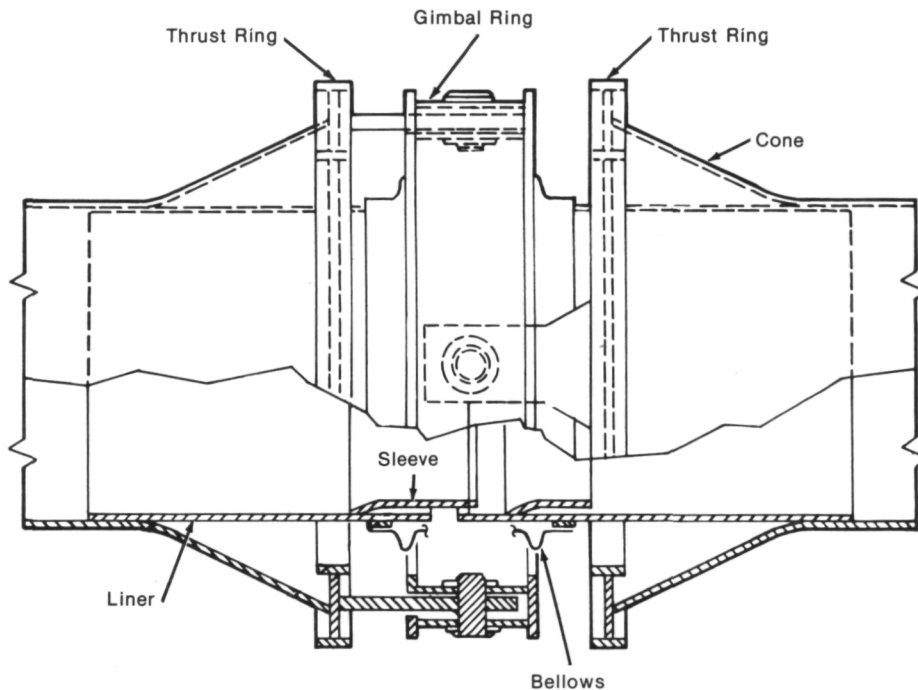


Figure 2. New Design

cone is attached to the pipe, but the major structural discontinuity is displaced to a region of lower temperature and thermal gradient where the cone is attached to the thrust ring. Providing a smooth transition at the small end of the cone and joining the liner to the pipe remote from the cone-pipe juncture further reduces discontinuity effects. As a result, warmup times were greatly reduced and no supplemental heating was required. These joints have been operated at pressures from  $1.04 \times 10^5$  to  $11.4 \times 10^5$  N/m<sup>2</sup> (15 to 165 psia) and at temperatures from ambient to 650° C (1200° F) without failures.

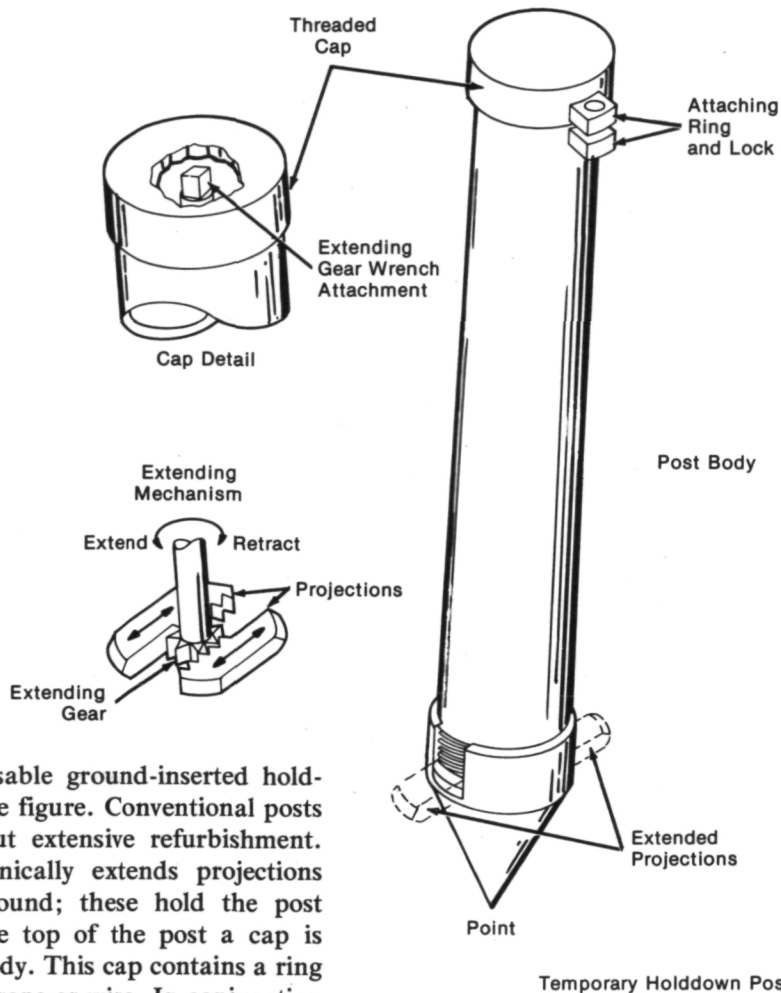
Joints of this improved design have been fabricated for NASA by a commercial joint manufacturer who is

incorporating them into his product line. The design principles used in the gimbal joints have also been applied to single hinged and universal joints ranging in diameter from 0.46 to 2.13 m (18 to 84 in.). Design pressures ranged from 0 to  $12.4 \times 10^5$  N/m<sup>2</sup> (0 to 180 psia) at temperatures of -45 to 650° C (-50 to 1200° F).

Source: James R. Winemiller,  
Suey T. Yee, and B. Holmes Neal  
Lewis Research Center  
(LEW-11705)

*No further documentation is available.*

### TEMPORARY HOLDDOWN POST: A CONCEPT



A temporary and reusable ground-inserted hold-down post is shown in the figure. Conventional posts cannot be reused without extensive refurbishment. This metal post mechanically extends projections horizontally into the ground; these hold the post securely in place. At the top of the post a cap is threaded over the post body. This cap contains a ring for attaching a retaining rope or wire. In conjunction with the cap ring, a mating ring on the body forms a lock for the rope. At the top of the post body is the top of an extending-gear shaft that can be rotated with a wrench. This shaft passes through the post body to the extending mechanism; here the gear-end engages mating gears on the inner surfaces of the projections, which are contoured to fit within the point diameter.

In actual operation the unit is driven into the ground, the cap is removed, and a wrench is used to turn the extending-gear shaft. This rotation forces the projections into the ground for a distance of one-half the diameter of the post. The post is then difficult to remove and can be used to tie down portable equipment or structures. Since the extensions can be retracted, the post is removed easily for reuse.

The use of an internal-gearing system to extend projections into the ground is believed to be unique. By keeping the size of the projections such that their points are flush with the outer diameter, there should be no difficulty due to malfunctions of the mechanism. Proper material selection would guarantee long life for the internal bearings and gears.

Source: J. G. Sandlin of  
The Boeing Co.  
under contract to  
Kennedy Space Center  
(KSC-10617)

*No further documentation is available.*

## Patent Information

The following innovations, described in this Compilation, have been patented or are being considered for patent action as indicated below:

**Transition Weld Joint for Aluminum/Stainless Steel** (Page 10) MFS-22313  
and

**Latch Mechanism** (Page 18) MFS-21606

Inquiries concerning rights for the commercial use of these inventions should be addressed to:

Patent Counsel  
Marshall Space Flight Center  
Code CC01  
Marshall Space Flight Center, Alabama 35812

**Bonded Joint With Tapered Insert** (Page 13) LAR-10900

This invention has been patented by NASA (U.S. Patent No. 3,809,601).  
Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

Patent Counsel  
Langley Research Center  
Mail Stop 313  
Hampton, Virginia 23665

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— NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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